(12) UK Patent Application (19) GB (11) 2 213 026 (13) A

(43) Date of A publication 02.08.1989

(21) Application No 8727948.5

(22) Date of filing 30.11.1987

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(51) INT CL[4]
H04L 27/22, H04B 9/00

(52) UK CL (Edition J)
H4P PAPD
H4B BG

(56) Documents cited
GB 2183974 A

(58) Field of search
UK CL (Edition J) H4P PAPD PAPS PAPX PJ
INT CL[4] H04B 9/00, H04L 27/18 27/22

(54) Control arrangement for a phase shift keying system

(57) In a control arrangement, for phase shift keying system, phase control is provided by means Z, W arranged to periodically dither the phase of a local oscillator V by adding and subtracting a phase shift to the output signal of the local oscillator. Integration means M,N is provided and arranged to integrate the moduli of received bit amplitudes during each addition and subtraction (dither) period. The difference P in the integrated valves during respective addition and subtraction periods determines a basis phase level upon which the dither is superimposed. For more extreme differences, frequency control S,T,X,U is also active. The dither enables effectively, narrow bandwidth for good control, and wider bandwidth for acquisition.

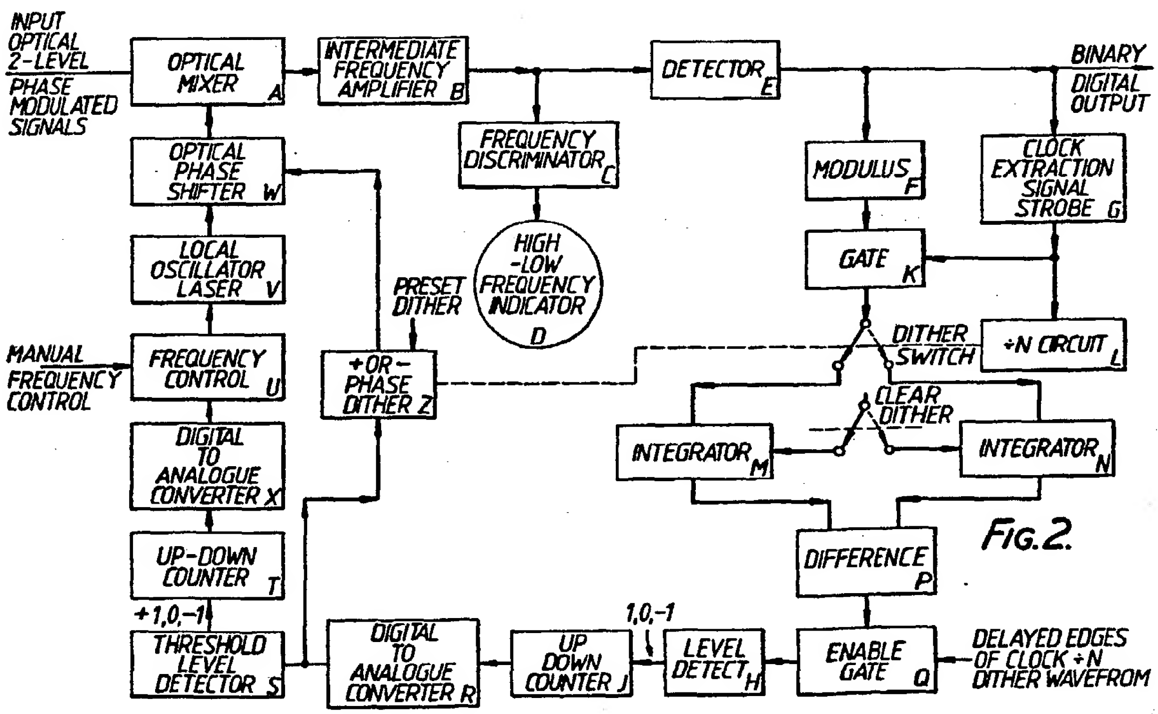

FIG.2.

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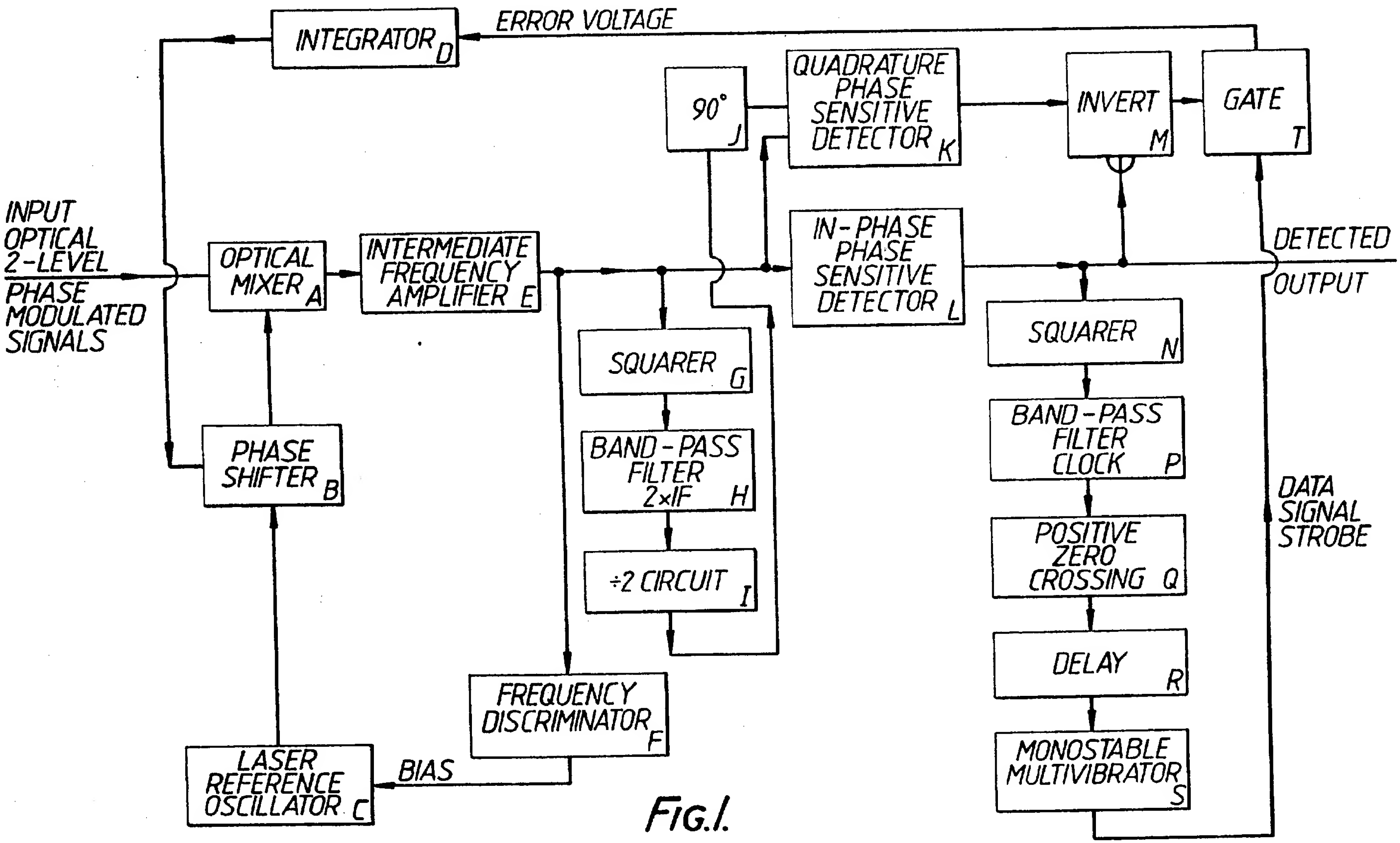
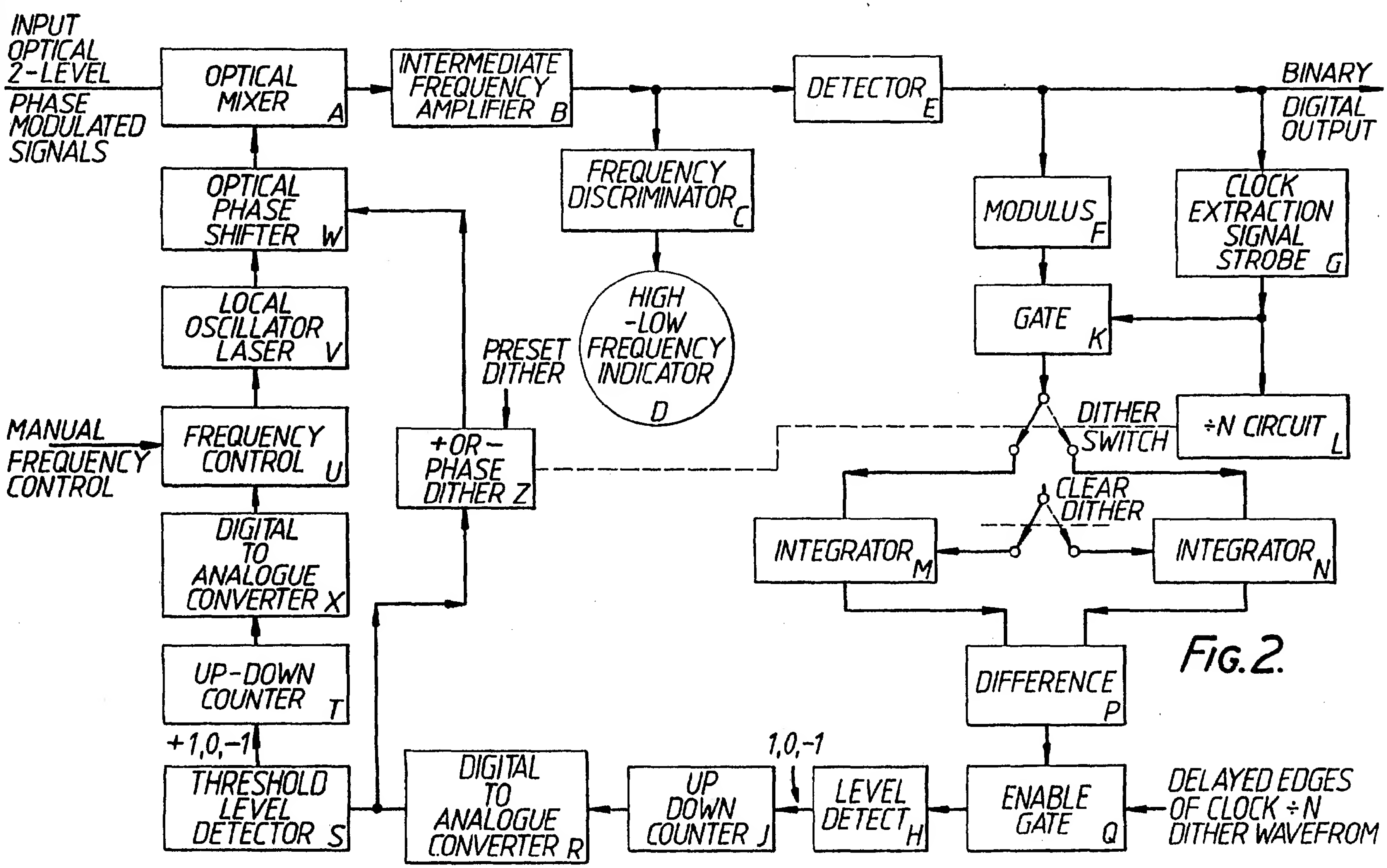


FIG.1.



INPUT OPTICAL 2-LEVEL PHASE MODULATED SIGNALS
OPTICAL MIXER A
INTERMEDIATE FREQUENCY AMPLIFIER B
DETECTOR E
BINARY DIGITAL OUTPUT
FREQUENCY DISCRIMINATOR C
HIGH -LOW FREQUENCY INDICATOR D
MODULUS F
CLOCK EXTRACTION SIGNAL STROBE G
GATE K
OPTICAL PHASE SHIFTER W
LOCAL OSCILLATOR LASER V
PRESET DITHER
DITHER SWITCH
÷N CIRCUIT L
MANUAL FREQUENCY CONTROL
FREQUENCY CONTROL U
+OR− PHASE DITHER Z
CLEAR DITHER
INTEGRATOR M
INTEGRATOR N
DIGITAL TO ANALOGUE CONVERTER X
UP-DOWN COUNTER T
DIFFERENCE P
+1,0,−1
1,0,−1
THRESHOLD LEVEL DETECTOR S
DIGITAL TO ANALOGUE CONVERTER R
UP DOWN COUNTER J
LEVEL DETECT H
ENABLE GATE Q
DELAYED EDGES OF CLOCK ÷N DITHER WAVEFROM

FIG. 2.

CONTROL ARRANGEMENT FOR A PHASE SHIFT KEYING SYSTEM

The present invention relates to a control arrangement for use in phase shift keying systems. The arrangement provided phase and frequency control. In the prior art, well known techniques are used in the design of a coherent heterodyne optical receiver systems where the transmitter uses 2-level phase shift keying (0° and 180°) of a continuous wave laser determined by a binary input data stream. Such techniques are shown in Figure 1 and will be described in detail later.

A problem occurs with such systems in that the frequency discriminator used needs to have a narrow bandwith for good control and a wide bandwidth for acquisition.

An aim of the present invention is to provide a control arrangement which does not suffer from the above mentioned problem.

According to the present invention , there is provided a control arrangement for a phase shift keying system, wherein phase control is provided by means arranged to periodically dither the phase of a local oscillator by adding and subtracting a phase shift to the output signal of the local oscillator, and integration means arranged to integrate the moduli of received bit amplitudes during each addition and subtraction (dither) period.

According to a further aspect of the present invention there is provided means for determining the larger of the two integrations obtained during each dither period, and further means is provided

arranged to use the larger integration to make a correction to the local oscillator's phase.

According to yet a further aspect of the present invention means is provided for controlling the frequency of the local oscillator.

An embodiment of the present invention will now be described with reference to Figure 2 of the accompanying drawings, wherein:

Figure 1 shows a known form of control arangement and;

Figure 2 shows a control arrangement according to the present invention.

Referring to figure 1, the incoming phase-modulated optical signal is mixed with the phase shifted optical output of the local laser reference oscillator (C). The output of the local oscillator is taken via phase shifter (B) to mixer (A). The output of the mixer is taken to the intermediate frequency amplifier (E). The output of (E) is taken together with a locally generated reference intermediate frequency to the phase sensitive detector (L) the output of which is the detected digital output. In practice the local laser may drift 1 Ghz in frequency for a temperature drift of 1 degree Celsius and hence needs precision temperature control (now. shown).

The frequency discriminator (F) takes its input from the output of the intermediate frequency amplifier (E) and generates a bias to control the current drive, and hence the frequency of the laser. A laser is expected to have a finite line width and additional phase correction is required from phase shifter (B). The control is provided by a carrier extraction circuit (G), (H) and (I). The incoming O°, 180° phase modulated intermediate frequency is first squared to generate a spectral component at twice the intermediate frequency.

The squarer (G) output is band-pass filtered in filter (H) at twice the intermediate frequency, and then halved in frequency by circuit (I) to give either sinusoidal or square wave output. This output, is phase shifted by 90° by circuit (J) the sinusoid, or delayed 1/4 of the period for the square wave, to give an input to the quadrature phase detector (K).

A clock extraction circuit (N), (P), (Q) and (S) used to strobe the in-phase and quadrtature signal outputs at the ideal sampling times.

The detected output is first squared by circuit (N) to give a component at the clock (data) frequency. This component is extracted by the band-pass filter (P). The zero crossing circuit (Q) genrates a pulse at each positive-going zero crossing of the waveform. These pulses are delayed at R to give optimum sampling time. The width of the strobe is determined by the monostable-multivibrator (S).

The phase-error correction circuit will now be described;

The output of the quadrature phase detector (K) should ideally be zero. The inverter (M) has no output to be gated by the clock strobes at gate (T) and the output of the integrator (D) is unchanged as is the amount of phase shift at circuit (B).

Suppose now that there is a small positive phase error with say the output of the detector (L)=0.866 and the output of the detector (K) =0.5 then if the inverter has no effect for positive output at (L), the integrator output will increase and the phase shifter (B) will need to be constructed such that a positive input increases the local oscillator phase and reduces the intermediate frequency phase. If the output of the detector (L)=0.866 and the output of the detector

(K)=0.5 then the output of the detector K will be inverted by circuit (M) to give the same effect. The quadrature signal multiplied by the sign of the in-phase signal defines the inverter output.

Referring to Figure 2 a coherent optical heterodyne detection arangement of 2-level digital binary phase-modulated signals is shown in which correction is made both for phase noise modulation and frequency drift of either the transmitting laser or the local oscillator reference laser or both.

The local oscillator laser (V) output is taken via the optical phase shifter (W) to mix with the incoming phase-modulated signals in mixer (A).

The output of the mixer in heterodyne operation will be a steady signal, depending on the incoming signal and local oscillator powers, together with a phase-modulated signal at some intermediate frequency.

The phase modulation is identical to that of the optical input signal if the modulated intermediate frequency lies within the pass-band of the amplifier (B) and if there is no frequency drift of the local oscillator.

The frequency of the local oscillaltor is controlled by its bias in the frequency control circuit (U). There will have to be very precise temperature control of the laser (not shown).

The frequency discriminator (C) consists of two tuned cicuits, one tuned higher, and one lower than the desired intermediate frequency. The difference between the two outputs after rectification, is integrated and taken to the high-low indicator circuit (D). This indicator could be used in an initial manual set-up of the

frequency of the laser acting as a local oscillator. It would be possible to use the output of the discriminator for an electronic initial set-up of this frequency.

The output of the intermediate frequency amplifier (B) is taken to a detector (E) which provides the output of the receiver in the form of a binary digit stream. The detector could take several forms. If the detector is phase sensitive, then a stable local oscillator (not shown) is required. Detection can also be achieved by subtracting two intermediate frequency outputs, one delayed by a bit period, provided that the intermediate frequency is harmonically related to the bit frequency, rectifying the result and performing a logical operation on the ternary output. This is a form of differential detection.

The detected output is taken to two other circuits, one being a signal strobe circuit (G) such as that shown by circuits (N to S) of Figure 1, the other (F) producing either the modulus or the square of the digital output, this being gated by the signal strobe. The signal strobe pulses are taken to a signal divider (L) which is shown as a ÷ N circuit. The output of the divider consists of two square waves in anti-phase with each other and with a period that is long compared with the bit period.

These waveforms are known as the dither waveform, and the objective of the invention is to dither the phase of the local oscillator. That is to periodically add and then subtract a small phase shift to the local oscillator and to integrate the moduli of the received bit amplitudes during each of the dither states. The larger of the two integration results is then used to make a permanent correction to

the local oscillator phase. In general, the correction will be smaller than the dither, however its sign will be that which increases the integrated output.

Figure 2 illustrates the dither output as a switch controlling the dither circuit (Z) with a preset dither phase level, and as a switch connecting the modulus of signal output to the analogue integrator (M) or to integrator (N). The difference between the integrator outputs is derived by circuit (P). The difference is gated by delayed edges of both the rise and fall of the dither waveform by gate (Q). The level detect circuit (H) is a 2-level threshold device having outputs of either +1, 0, or - 1 when gated, depending on whether there are significant differences ,either positive or negative, between the integrator outputs or if the difference is insignificant. The output of circuit (H) is taken to a digital up-down counter (J). The counter level is converted to a voltage in the digital to analogue convertor (R). This voltage is modified by circuit (Z) by the dither level and is fed to the optical phase shifter (W).

If the required phase shift becomes too large it would be outside the range of the optical phase shifter. If the phase shift required goes beyond say half the range adjustment provided, then a frequency change is required. This is achieved by a threshold level detector (S), an up-down counter (T) and a digital to analogue converter (X) which modifies the laser bias through the frequency control circuit (U).

The change in frequency is small and this will be governed by a preset adjustment, which in turn depends on the frequency stability of the lasers in use.

The following cycle of operations is required:

1. The integrator (N) is assumed to be charged at the beginning of the cycle.
2. The integrator (M) is cleared to zero.
3. The integrator (M) charges. The output of (N) is static.
4. The difference M-N is sampled.
5. The integrator N is cleared, and the dither switch changes over.
6. The integrator N charges, and the output of M is static.
7. The difference M-N is sampled.
8. The integrator M is cleared. Dither switch changes over.

Operations 3 to 8 are repeated.

The message must not be repetitive at the dither frequency and may be scrambled.

The magnitudes of the dither phase, the phase correction increment and the frequency correction increment are chosen as functions of the bit rate, the frequency stability of the transmitting and receiving reference lasers and number of integration cycles.

The above description is not intended to limit the scope of the present invention. Alternative arrangements falling within the scope of the present invention will readily be appreciated by those skilled in the art.

CLAIMS

1. A control arrangement, for a phase shift keying system wherein, phase control is provided by means arranged to periodically dither the phase of a local oscillator by adding and substracting a phase shift to the output signal of the local oscillator; and integration means arranged to integrate the moduli of received bit amplitudes during each addition and subtraction (dither) period.

2. A control arrangement as claimed in claim 1, wherein means is provided for determining the larger of the two integrations obtained during each dither period, and further means is provided arranged to use the larger integration to make a correction to the local oscillator's phase.

3. A control arrangement as claimed in claim 2 wherein the means which periodically dithers the phase of the local oscillator is a dither circuit having a preset dither phase level, and is controlled by a first switching means, a second switching means is provided which connects the moduli of the received bit amplitudes to one of two integrator circuits.

4. A control arrangement as claimed in claim 3 wherein the output signals from the integrator circuits are passed to a difference circuit, the output from which is gated by delayed edges of the rise and fall of a dither waveform, and passed to a first level detector which generate outputs of 0, 1 or -1 in accordance with the differences between integrator circuit outputs.

5. A control arrangement as claimed in claim 4 wherein the output signal from the level detector is processed by a first counter

means and then converted by a first converter circuit into a voltage which is modified by the dither circuit to generate an output signal which controls an optical phase shifter.

6. A control arrangement as claimed in claim 5, wherein frequency control is provided by passing the output signal from the first converter circuit to second level detector, the output from which is processed by a second counter means and converted by a second converter circuit, the output signal from which is used to modify the bias of local oscillator by way of a frequency control circuit.

7. A control arrangement as claimed in claim 6, wherein a change in frequency is only made when the required phase adjustment exceeds predefined limits.

8. A control arrangement substantially as hereinbefore described.

9. A control arrangement substantially as hereinbefore described with reference to Figure 2 of the accompanying drawings.

Published 1989 at The Patent Office. State House, 66/71 High Holborn, London WC1R 4TP. Further copies may be obtained from The Patent Office.
... Printed by Multiplex techniques ltd, St Mary Cray, Kent, Con. 1/87